A GLANCE AT THE ZOOLOGY OF TO-DAY

By Professor H. V. WILSON

THE UNIVERSITY OF NORTH CAROLINA

WHEN zoology is mentioned, our first thoughts turn to the different kinds of animals, to the so-called species; to the birds and insects round our homes, to the fish we have caught; to the less familiar forms of the coast, the sponges, medusæ and corals; to the beasts we have seen in zoological gardens, to the specimens exhibited in museums. This richness in variety is pleasing to most of us, and it is small wonder that the work of collecting and describing has been so actively pursued. The forms of animal life sufficiently different to be enrolled as separate species now number about half a million.

Strange as it may seem, one still at intervals hears the question, "what is the use of all these creatures?" meaning their use to us, to man. Perhaps the question is never very seriously asked to-day. For we all know a long list of organisms who, if they bring us tribute, bring a strange kind. We think of that prince of evil, the tiger; of the cobra; of parasitic worms that bore through the living flesh; of bacilli that bring disease after disease; of protozoa that cause malaria and sleeping-sickness. And we recognize that the material world is not obviously anthropocentric.

Modified, however, the question is a very rational one: what forms are inimical to us, what forms directly or indirectly useful? This question, essentially economic and hygienic, tends greatly to increase our interest in natural history, in the knowledge of the kinds of animals, and the changes of form, habit and home which they undergo during individual life. We become aware how complex are the interdependencies of organisms, how interwoven are their life-histories. We find that it is largely on such knowledge that the medical scientist and the sanitary engineer draw when they seek to combat the infectious diseases, and how vitally helpful such knowledge is to the various branches of animal industry.

These considerations show us plainly enough that biology is useful, and in making this statement we perhaps express the real nature of our knowledge in general, as something not final and comprehensive, but detailed and practical. Let us, however, not confound this aspect of the nature of knowledge with the method of science. Because the world is so ordered, and its ways so interconnected, that any or all knowledge may after a time prove useful, is no reason why we should concentrate

our attention chiefly on tasks and problems that are of immediate practical importance. On the contrary, as we survey the history of science, we see clearly that inquiries into the causes or beginnings of things, irrespective of direct utility, are of the first importance. It is these which lead to the emergence of the great general ideas, which, in their turn, light the way to the discovery of special facts that are of direct utility.

Turning from the utilitarian aspect of biology, let us take up for a moment a problem which, never new, is yet always interesting. What is the origin of all these forms that we have learned to know? What is the nature and origin of species, or, choosing the phraseology of the day, of specific differences?

In the histories of the theory of evolution we read, wondering if any of our present-day notions shall prove as untenable, that Linnæus held that species were changeless, that they were in character and number precisely as originally created. We read that somewhat later, when fossils were better known, Cuvier interpreted the present organisms and the very different ones of past geological periods as the results of separate acts of creation, each period with its living things coming to an end in some tremendous catastrophe. And that still later Louis Agassiz held the same view, while meantime he with many others paved the way for evolution by discoveries of fact, bringing to light the existence of fossil series from low forms to high, and many illustrations of the generalization embodied in our "biogenetic law" of to-day, namely, the generalization that organisms do not pursue a straight path of development from egg to final form, but commonly develop temporary peculiarities of structure constituting resemblances to lower forms.

The strong tide of evolutionary doctrine that set in with the publication of Darwin's great book in 1859 brought nothing new to what had been taught by Louis Agassiz as regards the existence of the resemblances, just alluded to, between organisms, adult, embryonic and fossil. But that the stream of living matter has been continuous from generalized type to derived form, or, as we say, from ancestral type to descendant, this is the conception that rings out the note of difference from Agassiz's teaching. Basing its argument on minor mutability that can be demonstrated and on a mass of circumstantial evidence, overpowering in its cumulative effect, evolution claimed that fundamental resemblance is not a transcendental likeness, but is due to kinship. With this conclusion we are long familiar. It has entered into the very marrow of our mental life, and everything that we learn corroborates it. The conclusion concerns us in a direct way, for the evolutionary process can not be thought of as something finished and done with. Rather do we conclude that if organisms *have* changed, they are still changing.

Granted the fact that organisms change, the question veers and we

ask in response to what do they change? Are the changes natural phenomena throughout and, as such, due to natural causes, like the up and down heaving of the earth's crust?

We are confronted to-day, as in past times, with two interpretations of nature. On the one side argument, clad in the robe of philosophy, would lead us beyond the border of the phenomenal world, seeking a reality on which all phenomena are dependent. Many tell us there is such a reality—and certainly nothing that we know contradicts them. On the other hand, the obvious world is a world of natural phenomena, which, although at bottom incomprehensible, prove on study to be orderly and predictable. That is, we learn through experience that one occurrence is associated with another, that one change brings about the next, that for every effect there is a cause.

Returning to our question, it may be said that we work and work successfully on the theory that the changes which organisms undergo are natural phenomena brought about, like any others, by natural causes. The transformation of a horde of barbarians into a modern European nation; the immunity which a race acquires against specific disease; the evolution of new breeds of dogs, horses and wheat; the spreading of a race over a wide and varied area with the consequent appearance of differences which mark off the group into geographical subgroups; the gradual loss of parts of the body, so obvious in some fossil series; the metamorphosis of a part into what is virtually a new organ; the restriction of a species to a narrow area of distribution, with the final outcome, extinction; all these we are justified in regarding as natural phenomena and as phases in the wave of change that incessantly passes over living nature.

Granted the fact of change and that it is a natural phenomenon, we become interested in the analysis of its causes. And so we begin to inquire into the origin and accentuation of the small differences which mark off a race from the parent stock. Thus we pass from the wider study of evolution to the narrower and more precise study of heredity and variation. Here the experimental method is the chief one employed, although often under the guidance of comparison and statistics.

I pass over the ideas entertained as to ways in which differences are accentuated and touch, in preference, on some of the ways in which they originate. We know very well that the body of an animal, its skin, bones, muscles, etc., made up of infinite numbers of microscopic components, the cells, responds to changes in exercise, food and environment with the production of differences which are often very well marked. But we also know that the great bulk of the obvious and familiar differences so caused are not passed on to the next generation. They are not heritable. In order to be heritable, the peculiarity must be lodged, potentially, of course, in the germ cells. These are the cells,

commonly ovum and sperm, which, leading a life aloof from the body cells, give rise to the new individual.

We may then ask, do all individual differences that are heritable originate from the very start in the germ cells, and, if so, owing to what influences? or are there subtle changes of the body cells induced by habit, food and environment, which are transmitted to and lodged in some potential form, in the germ cells? This two-sided question, it is obvious, concerns mankind in a very practical way. It has been argued warmly for many years, usually under the heading of "the inheritance of acquired characters," and still to-day, in a more clearly circumscribed shape than formerly, makes one of the most important general problems of experimental biology.

In past years it was widely held that the transmission from body to germ was a fact, in other words, that peculiarities developing for the first time in the body, not as the result of congenital constitution, but as the result of habit or outward circumstance, were transmissible to the germ. Weismann and others have shown that much of the evidence on which this conclusion rested is weak, and the result of their criticism has been in some measure to discredit the idea. There are, nevertheless, certain experiments which, while not demonstrating transmission from body to germ, do demonstrate perhaps the more important fact that the effect on the body of outward circumstance in one generation may be in some degree repeated in the bodies of the next generation, although the conditions which first induced the change are no longer operative.

Prominent among such experiments are the classic investigations of Standfuss and Fischer on European butterflies. Both Standfuss and Fischer showed for certain species that the temperature at which the pupal stage is kept, during its so-called sleep, may be made to affect very seriously the coloration of the butterfly into which it metamorphoses. In this way by employing temperatures above the normal and temperatures below the normal, butterflies are obtained very different in appearance from the type.

Standfuss having in this way obtained strongly altered individuals, bred from them, keeping the butterflies and their offspring not at the abnormal temperature which induced the change, but at the normal temperature. The great bulk of the offspring, the second generation of butterflies, proved to adhere to the usual type of the species. Nevertheless, a few examples departed from the type and resembled in varying degrees their parents.

In a similar experiment, Fischer subjected pupæ to an intermittent cold of —8° C., and in this way obtained butterflies different from the type. The offspring of these modified individuals fell into two groups, those adhering to the type and those resembling in greater or less degree the modified parents. The percentage of the latter was a considerable one.

These and numerous other experiments (such as those of Schübeler on German wheat transplanted to Norway and back again, the work of Tower on the potato beetle, that of Sumner on breeding mice at low and high temperatures, etc.) unquestionably show that the environment can exert a modifying influence on the hereditary constitution of a race, that it can originate heritable differences between organisms. They show, moreover, that it sometimes happens that a definite change is made in the body and a corresponding change in the germ cells, the change in the body of the first generation, thus showing in a measure what the heritable effect on the race will be. These important experiments mark a real advance, and it is safe to predict that they are but the precursors of many more dealing with the effect of the environment on the germ cells. At present one can not but feel that the amount of evidence is too slim to decide the question as to whether the environment first produces an effect on the body which is then transmitted to the germ cells, or whether the environment acts directly upon the germ cells, producing in them potential changes parallel to those produced in the body.

A second way in which heritable differences between organisms originate, that is, a second way in which changes in the properties of the germ cells are induced, is through amphimixis or development from two parents, wherein two sets of hereditary tendencies are intermingled.

Adopting this general method, investigators have in recent years attacked the problems of heredity and variation from two sides. On the one hand, students of experimental embryology, cross-fertilizing the egg of one species with the sperm of another, have occupied themselves in tracing the influence of the respective parents as displayed in the growth and differentiation of the hybrid germ. Sea urchins, frogs, fish are the objects which more than others have been used for such studies. This is too technical a field to admit of brief description. If there were time it would be easy to show that the connections between the study of embryology and heredity are numerous, close, and indeed fundamental to any real understanding of either.

The other great application of the method of cross-breeding to the study of heredity concerns itself not with the gradual individual development but with the reappearance of the characteristics of adult organisms in the offspring and later descendants. In this study a remarkable activity now reigns, dating from the year 1900, when certain principles of hereditary transmission, originally discovered by Mendel and published in 1865 but subsequently lost sight of, were rediscovered by several European botanists. These principles lie at the center of that collection of data, law and explanatory hypothesis which we designate Mendelism and which is the outcome of a vast amount of experimental breeding of animals and plants of many kinds.

The fundamental principles of Mendelism are no doubt familiar to

many of you. In this study attention is concentrated not upon the influence which one parent as a whole exerts upon a descendant, but upon the transmission of particular characteristics. The characteristics to which attention is paid are those in which the two parents differ sharply. They are contrasting characters like blackness and whiteness of fur in the rabbit, tallness and dwarfness of the pea vine, roughness and smoothness of coat in the guinea pig.

The conclusion of fundamental importance is that such characters do not blend in the descendants, but are passed on from generation to generation in their original distinctness. The characters, Mendelian or unit-characters as they are called, may be obvious or latent. In the familiar case of rabbit breeding, when a black and a white rabbit are bred from, the offspring are all black, but whiteness is latent in some, for if the black offspring are interbred, a certain proportion of white rabbits will appear among the grandchildren.

A point of importance is that the Mendelian characters of an ancestor behave in heredity independently of one another in such wise that new combinations may be made. Thus, if a dark, smooth guinea pig be bred to a white rough guinea pig, and the offspring be interbred, the grandchildren will be of four kinds, with respect, that is, to the qualities darkness and whiteness, smoothness and roughness (W. E. Castle). Some will be like the grandfather and some like the grandmother. But there will be other grandchildren like neither of the grandparents. In these a grandfather feature is combined with a grandmother feature, and so we get dark rough and white smooth pigs.

Thus qualities which exist apart from one another in separate organisms may be combined in one and the same individual, and new breeds be created. In such new breeds it is apparent that new qualities are not created. What is created is a new combination. This is heritable and therefore marks off the breed from others. Hybridization here, then, originates heritable differences between organisms. It may be added that the independent behavior of Mendelian characters in heredity is not necessarily equal throughout a long series of characters. In other words, characters sometimes, perhaps always, tend to reappear in groups. This important fact has been especially brought out by recent work on the heredity of the little fruit-fly, *Drosophila* (T. H. Morgan).

In a loose and general way it has always been known that new combinations of characters occur in organisms bred from two parents. In this connection Goethe's verses have often been quoted by Haeckel and others:

> From father I get my height
> And my earnestness;
> From mother dear my gladness of nature
> And delight in romancing.[1]

[1] "Vom Vater hab' ich die Statur," etc.

But Mendel's achievement was to discover order where no order had been recognized, to demonstrate that the combinations which are made are of a constant character and, moreover, are embodied in groups of grandchildren numerically proportionate to one another. We have seen that where, as in the case of the guinea pigs, two pairs of characters are considered, there will be four kinds of grandchildren. It may be added that in such a case the four kinds will be represented by the proportional numbers 3, 3, 9, 1. That is, for three of one kind, there will be three of another, nine of another and one of yet another. The larger the number of contrasting points, the greater will be the number of kinds of grandchildren. Thus Correns, one of the rediscoverers of the Mendelian principles, calculates that if the first parents differ in respect to ten points there will be more than a thousand different kinds of grandchildren.

Mendel's explanation of the phenomena that now bear his name was in the shape of an hypothesis which with various alterations, some of which are important, is in general use to-day. He conceived of each contrasting character as potentially represented in a germ cell by a particular "something." This something we speak of as a germinal factor, a unit-factor or a gene. It is thought of as a definite entity. Many, indeed, perhaps most, look on it as a material particle. Others do not make the attempt to visualize it. When the egg and sperm fuse, corresponding germinal factors are brought together in pairs, each pair of factors representing a pair of contrasting characters, blackness and whiteness of rabbit fur, for example. Thus brought together in the fertilized egg, the two factors of a pair may each produce an effect on the body of the organism into which the egg develops. Or one factor may completely dominate the other, the organism bearing the impress of that factor alone, the other lying dormant. When, for example, in the egg of the rabbit, the factors for blackness and whiteness are brought together, the factor for blackness being dominant, the egg develops into a black rabbit. But now as the germ cells are formed which will give rise to the next generation, the factors are supposed to be sorted out among them in such wise that any one germ cell does not get both, but only one, of a pair of factors. Thus, in our example, eggs will be produced having the factor for blackness only, and others the factor for whiteness only. Similarly with the sperm cells, some will have the factor for blackness, some that for whiteness. No germ cell will have both factors. This separation of the factors with the result that the germ cells produced in an individual are unlike, is the most important feature of the Mendelian hypothesis. Working on this hypothesis, it can be calculated what will be the proportionate number of individuals embodying any particular combination of characters which, through experiment, have been found to behave in Mendelian fashion. The hypothesis has received wide and striking confirmation in that the

results of the actual breeding experiments agree closely with the calculated expectations.

Such extensive use of the unit-factor hypothesis has been made that in the graphic language of the day an organism is sometimes depicted as a bundle of separate qualities, of so-called unit-characters, each the outcome in mechanical fashion of a single discrete germinal cause, which does not vary and which is self propagative. Viewed in this artificial light, biology assumes a rigid appearance far from its real nature, its task appearing twofold, to discover through cross breeding the elementary or unit characters of organisms and the laws governing their combination.

It should be said that such a conclusion is implied rather than positively stated in the writings I have in mind, and is expressly condemned by some prominent students of Mendelian heredity (T. H. Morgan). The facts of paleontology, anatomy and development demonstrate how artificial it is, for they show that every part and process varies among the individuals of any one time, and the *mode* or typical condition changes from age to age. Moreover, the parts of the body are so interconnected materially and their activities or functions are so interassociated, that to speak of the body as a group of units is misleading. It is to misuse the license that is only allowed in allegory, or in science for the purpose of facilitating description. A tiled floor is composed of pieces which can be taken apart and recombined. But an organism, Olivia for instance, is not a mosaic, for the items in her inventory, as "two lips indifferent red, two grey eyes with lids to them" are not separate and independent components. The essential features of an organism appear to be as closely associated, fully as inseparable, as are the corners, cleavage, color and lustre of a crystal, of calcite, for example. For given the right conditions, the germ cell or other regenerative mass will always produce them.

I hasten to remind you that "unit-character" in technical studies on Mendelian heredity has a definite meaning, referring to the class of differential features, which mark off the individuals of a race, or of allied races, one from the other. Such would be the color of the eye perhaps, or the fulness and curve of the lip. It is, as already said, these contrasting features in respect to which the two parents differ, which behave independently of one another and which may therefore be recombined in various ways.

The question as to the permanency of such characters in hereditary lines is interesting to all of us. There is no doubt that they are remarkably constant and persistent, but experimental breeding amply demonstrates that they are subject to the sudden changes known as mutations. It has also been demonstrated that in the course of selective breeding they undergo change (W. E. Castle). They show then, as do the many series of intergrading organisms, that the rule of heredity over living things is not absolute. Living things, in fact,

continually escape from its tyranny through modification of their germ-cell substance, modification which is brought about through interaction with the environment and through interaction with other germ-cell substances, the latter action leading not only to new combinations of the old, as in ideally strict Mendelism, but to actual change in the specific protoplasm, with the result that what are virtually new qualities emerge.

Mendelism has enormously increased the general interest in heredity, than which no subject in the whole field of science is more discussed to-day. In the midst of the discussions and admirable investigations dealing directly with this matter, it is well not to forget what heredity is. As Haeckel pointed out long ago, heredity is not a special organic function, but is only a name for the fact that the specific substance of the germ cell exhibits a set of properties substantially like those of the parent germ cell. In other words, heredity means that an egg behaves very much as the parent egg did, because, having essentially the same organization, it reacts to stimuli in essentially the same fashion. A sound knowledge of heredity is therefore dependent on a knowledge of the ways in which the many kinds of protoplasm respond to stimuli; in other words it is dependent on the general level of biological science.

In conclusion, let me say that the several aspects of zoology at which we have glanced has each an interest in itself. Otherwise there would be no hope of advance. But they fade into one another. The data overlap and the problems merge. The geographical explorer, dealing with the distribution of animals; the classifier, discovering and arranging the diagnostic features of races and species; the descriptive anatomist skillfully tracing out details of structure in finished product and embryo; the comparative morphologist, outlining embryological sketches and life histories and applying his data to questions of evolution; the analytic embryologist, unraveling physiological factors, control of which enables him to bring into being the differences which he started out to explain; the student of hereditary transmission recording the way in which characters reappear, and his other half, the student of variation, who experimentally induces new differences—these and many others are all dealing with one and the same nature, the many-sided world of living and once living things of which we form a part. The various classes of phenomena exhibited by this world of organisms, as they are mapped out and in some degree analysed, enter into and constitute biology. They form a vast and heterogeneous array, of which it may be said that the vastness will remain, will indeed steadily increase, but the heterogeneity should become less evident. For as knowledge grows and hypothesis gives way to generalization, the various aspects of the living world will no doubt arrange themselves in a more and more coherent manner, that is, we shall be more and more able to assign them to empirically learned causes, to the fundamental powers of the group of protoplasms as shown in responses to stimuli.